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Towards a Collaborative Decision Support System for the Freight Transport: a Pilot Test-Based Analysis

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Abstract: Collaborative Decision Support Systems (CDSSs) have been increasingly used to organize collaborative transport networks to develop sustainable freight transport. CDSSs involve two main components: a collaborative planning algorithm for matching transport orders to trucking capacities and an interactive front-end (e.g., websites and Email systems) for dispatching freight matches and communication among collaborators. The literature has mostly focused on developing and testing advanced algorithms using historical data. However, these studies test only one component and ignore the front-end that greatly affects the CDSS performance in daily practice. Overall, the literature lacks studies that evaluate and improve the CDSSs based on the feedback of end-users with a pilot test. Though poor data availability and quality are well-known issues in the logistics industry, no previous studies have discussed how to deal with the data issues in the real applications of CDSSs. To bridge these gaps, this study reports our experiences with testing an early version of a CDSS for automated freight matching in Denmark. The test results revealed some issues related to the ease of the CDSS usage and validity of the identified matches. A methodology is proposed to analyze the test results and to inspire ideas for improvement. The analyses showed that low data quality (e.g., missing values) is a significant barrier to developing effective front-end and valid matching. Due to the low data quality, automated matching can be more effective if carriers set their matching preferences through access to the CDSS. Besides, the front-end Email system should be developed in a way that reduces the number of emails, enables snap judgment, and visualizes the match details. Finally, some improvement suggestions are proposed and evaluated.

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Keywords: Decision support systems, Freight, transport, Collaboration, Email, Data quality.

1. INTRODUCTION

The freight transport market is highly fragmented. As a result, freight carriers are facing operational challenges such as low load factors and high operational costs. In 2018, Eurostat (Eurostat, 2021) reported that on average, 22.5% of the journeys made by trucks was empty running in most European countries. As a sustainable practice, carriers collaborate on their transport activities to improve their truck utilization and profits (Karam et al., 2020). The first step towards collaboration is that a carrier finds a suitable partner to collaborate with. Such a step is not an easy task and represents a significant barrier to collaboration. To overcome this barrier, carriers often join a collaborative transport network organized by a third-party CDSS (Creemers et al., 2017). The CDSS is typically implemented as an interactive web-based system including three main parts: database, matching algorithm, and communication client such as Email system or web-based platform (Power, 2002). In most collaborative networks, carriers share their information of transport orders and trucking capacities with the CDSS that matches freight to available trucking capacities. Since CDSSs connect transport networks of several carriers, carriers can quickly find the right collaboration peers. Additionally, the process of matching hundreds of transport orders to several trucks takes only few minutes by using advanced matching technologies. This brings a significant added-value to the collaborative practices since manual matching requires many phone calls, and carriers might spend 50 to 75% of their time to find feasible matches (Lockridge, 2019). A considerable number of studies have developed complex matching algorithms utilizing several variants of the vehicle routing problem (Gansterer and Hartl, 2020). Regardless, few studies addressed the real applications of CDSSs in the freight industry (Basso et al., 2019). Before using the CDSS in practice, the CDSS should be extensively tested to ensure its validity, efficiency, and ease of use. Generally, real applications involve two testing steps: the DSS is firstly evaluated in a controlled environment using simulation

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approaches and historical data, and second, the DSS is tested in real use, during a number of pilot tests (Burstein et al., 2008). The few studies implementing CDSSs have only shown the results from applying matching algorithms to test cases or historical data (Creemers et al., 2017; Dahl and Derigs, 2011; Tarantilis and Kiranoudis, 2002). These studies did not discuss their experiences with pilot-test based evaluations of the CDSSs. Pilot-testing results would be beneficial to IT developers, researchers, entrepreneurs, and logistics companies who want to develop and implement CDSSs in the freight transport sector. This is because such results can inform potential implementation issues that might not be apparent at the design phase nor when applying historical data to an algorithm. Besides, they constitute the best practices for developing and implementing CDSSs and provide many practical insights on how to solve implementation issues. In addition, little attention has been paid to the front-end performance, which greatly affects the CDSS usage in daily practice. Although many studies confirmed that poor data availability and quality cause several issues in real applications (Raweewan and Ferrell, 2018). However, no previous studies have - to the best of our knowledge - presented some suggestions to deal with this issue in real applications.

This study presents our experience with pilot testing of an early version of a CDSS within the research project DiRECTLY project. The developed CDSS aims to enable two large Danish carriers to identify efficient freight matches among their transport orders and trucking capacities. Through the DiRECTLY-CDSS, both carriers can improve their load factors and reduce the empty traveling distance in a win-win solution. In particular, the current work discusses the issues of the CDSS reported during the pilot test. Additionally, we propose a methodology to analyze the pilot-test results. Finally, some solutions to the identified issues are suggested and evaluated.

This paper is structured as follows: Section 2 describes the DiRECTLY-CDSS while section 3 presents the pilot-testing results. Then, section 4 presents the methodology used to analyze the test results. Section 5 discusses the analysis of the test results and possible improvement ideas. Section 6 evaluates the suggested improvement ideas. Finally, section 7 presents the conclusions.

2. DiRECTLY-CDSS

Fig. 1 shows the architecture of DiRECTLY-CDSS that is composed of a centralized database, matching algorithm, and email client. The proposed CDSS enables automated freight matching, meaning that no humans are needed since logistics data automatically flow from carriers' systems to the CDSS, and all possible matches are automatically identified. The developed DSS entails interactive information flows in chronological order as follows: at the early morning hours of each day, the logistics data are shared with the centralized database system. Then, a matching algorithm processes the shared data to determine feasible insertions of pickup and delivery locations of orders into the planned routes of trailers or trucks. An email client acts as a central interface for composing and sending emails about the identified matches. The idea was not to 'merge' the two carriers, but to utilise excess capacity through collaborative transport. Therefore, the carriers required that the CDSS identifies and sends two types of matches, namely order matches and trailer matches. For example, if a transport order is matched to the route of a trailer, the order owner (the partner who has the order) receives an order-matching email while the trailer owner (the partner who has the trailer) receives a trailer-matching email. In other words, each partner receives order-matching emails for transport orders and trailer-matching emails for trailer routings in one inbox. Based on the carriers' requirements, the project team designed email templates and ensured that they provide insensitive but sufficient information so that dispatchers can make 'accept' or 'reject' decisions on the match. Fig. 3 shows the email templates. Each email template has three main parts, i.e. subject line, content, and a hyperlink. The subject line describes data items of the identified match. At the template bottom, the hyperlink enables dispatchers to communicate their interest in the match with their partners.

After developing the first version of the CDSS, a verification test was conducted by running the CDSS without involving the companies' dispatchers, but involving a few lower-level managers in the companies. The verification test mainly aimed to ensure that the CDSS configurations operate correctly without bugs and that the Email system works correctly. Afterward, pilot testing was planned to test the CDSS in real use and to investigate how easy the developed DSS is to use by dispatchers. Pilot testing also enables early detection of flaws in the CDSS before the full release.

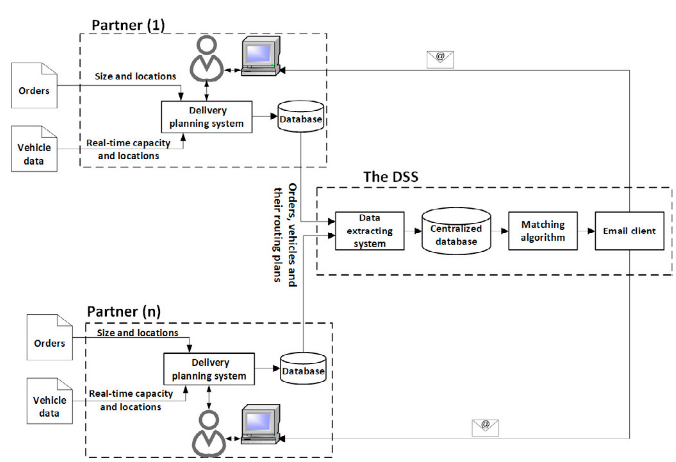
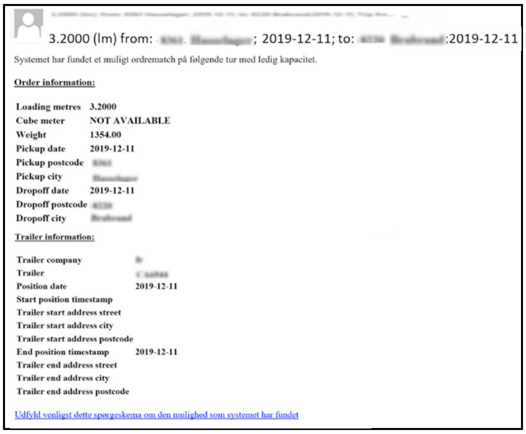


Fig. 1. Architectural diagram for the DiRECTLY-CDSS.



(a)

(b)

Fig. 2. Screenshots for trailer-matching email (a) and order-matching email (b).

3. PILOT TESTING RESULTS

Pilot testing aims to verify the main functionalities of the CDSS under a real-time operating environment. Compared to the verification test, the pilot test enables us to ensure that the Email system provides an effective and appropriate user interface while satisfying end-user requirements for sufficiency and privacy of information, and ease of use in relation to daily work practices. Before conducting the test, the project team held introductory sessions with dispatchers on the aims of the pilot test and their roles in the test. The pilot test was scheduled for one month starting from 13th November 2019 to 13th December 2019. During this period, dispatchers received matching emails from the CDSS. Additionally, they were asked to review and respond to emails, typically, while one of the project team observes them to identify where they face problems and experience confusion. The observers where physically present in the companies during the test, which also allowed for a broader identification of potential problems. In particular, we aimed to test the following aspects:

Test aspect#1: *How easy it is for dispatchers to read the matching emails without confusion.*

Test aspect#2: *If the templates provide enough information for dispatchers to decide on the matches.*

Test aspect#3: *To what extent the dispatchers could review all emails received during the workday.*

Table 1 shows the representative feedbacks of dispatchers. As shown in Table 1, the feedbacks highlighted some issues with the CDSS.

Table 1. The feedback of the dispatchers

Test aspects	Representative feedback from dispatchers
Test aspect#1	• Multiple copies of the same order-matching email are received at the same time. • Dispatchers could not make a snap judgment from the email subject line and had to read the email content to get the message, which is time-consuming. • Trailer-matching emails are relatively long and require using scroll down. • Trailer and order matching emails have the same subject-line structure. This does not allow for differentiating between the two mails without opening them.
Test aspect#2	• The emails provide enough information but many information items were missing or illogical. • Order-matching email lacks an order ID that is used internally in the company. • Some dispatchers indicated that some matches are not correct, for example, matches for already served orders.
Test aspect#3	• The number of matching emails is significant and it was not possible to review all of them.

Because dispatchers' feedbacks alone cannot provide insights for solving these issues, it was necessary to gain better understandings of the CDSS performance during the pilot test. This was done by analyzing the logistics data as well as identified matches during the pilot test as will be illustrated in the next section.

4. THE PROPOSED ANALYSIS METHODOLOGY

Fig. 3 shows the proposed methodology used to understand the root causes behind the identified issues and to gain some insights to resolve these issues. The proposed methodology includes four steps following the CDSS pilot test (steps 1 and 2). As shown in Fig. 3, the methodology starts with generating an initial set of questions. Each question directly reflects on one identified issue or more. The initial set of questions are as follows:

Q1: How can the daily numbers of matching emails be reduced?

Q2: How can the templates be redesigned to enable snap judgment about the email content?

Q3: How can the matching emails be improved and its content be effectively visualized?

Q4: What are the causes for the multiple copies of the same order-matching email?

The first question addresses the most challenging issue, i.e. the considerable numbers of matching emails. Each carrier received a daily average of 322 matching emails during the pilot test. One may think that this issue can be solved by developing constraints on transport requirements, e.g., delivery and pickup times, and a class of trailer. However, this was not recommended since the preliminary analysis of shared logistics data showed that only pickup and delivery locations of transport orders are reliably documented while most of the other information is estimated based on the dispatchers' experience. Therefore, the matching algorithm only considers the trucking capacity and a deviational distance limit between the matched trailers and the pickup locations of the orders. Following the creation of the questions, the next step is to answer the questions. To do so, the project team conducted a deeper analysis of the shared logistics data and the identified matches. Shared logistics data were analyzed to develop a clear overview of the missing information. Additionally, temporal and size analyses of the identified matches were conducted. The temporal analysis was focused on time and hourly distributions of the identified matches while size analyses addressed the frequency distributions of matches with respect to order sizes. The results of the questions inspired some solution ideas and attracted our attention to some observations that were not apparent to the project team before the pilot test as will be discussed later. After answering all generated questions, the research team suggested possible solutions for the identified issues, followed by evaluating the impact of proposed solutions on the system.

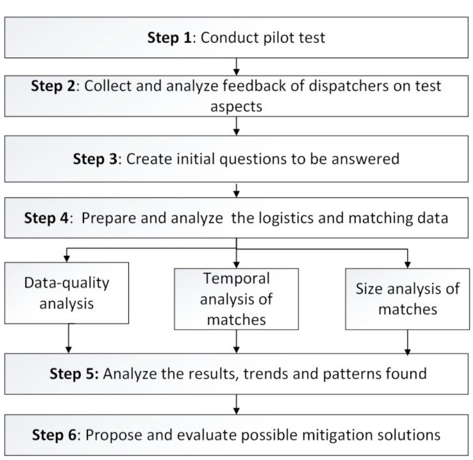


Fig. 3. The analysis methodology of the pilot-testing results.

5. RESULTS

This section is divided into two parts. The first part presents the results of the data analysis. It also shows the insights from the results and how they can be used to propose some Improvement Suggestions (ISs). The second part summarizes and evaluates the impact of the ISs. In the following, the two carriers are referred to as DF and FR. It should be noted that as the pilot test progresses; errors in matches are detected and corrected. Therefore, to ensure valid matches, the analysis period is set to the last five days of the test month, from December 9th to 13th, 2019.

5.1 The results and ISs

Fig. 4 shows the percentages of missing values in the shared logistics data. Compared to data of weight and loading meter, data of cube meter, expected pickup and delivery times have relatively significant percentages of missing values. This is because loading meter is often the most precise 'size' indicator for most freight. Note that missing values are displayed in the email templates as 'NOT AVAILABLE' (see Fig. 2). Thus, we suggest IS1: removing these three data items for improving the readability of templates. IS1 is reasonable since dispatchers if accepted the matches, must communicate and reveal more information about delivery schedules. Since weight and loading meter data are important, transport orders lacking loading meter and/or weight data might not attract the attention of dispatchers. Thus, we suggest IS2: orders lacking loading meter and/or weight values are not matched. This in turn reduces the number of matches and their corresponding matching emails. Another interesting observation from Fig. 4 is that although the DF carrier's data lacks expected pick-up times, around 32% of its orders have expected delivery time. Thus, it is worth investigating the effect of using these available delivery times on filtering the identified matches rather than ignoring them. A similar observation can be noted for FR carrier's data of delivery and pickup times. Thus, two improvement suggestions are raised as follows; IS3: Incorporate a constraint on expected pick-up times into the matching algorithm, and IS4: Incorporate a constraint on expected delivery times into the matching algorithm.

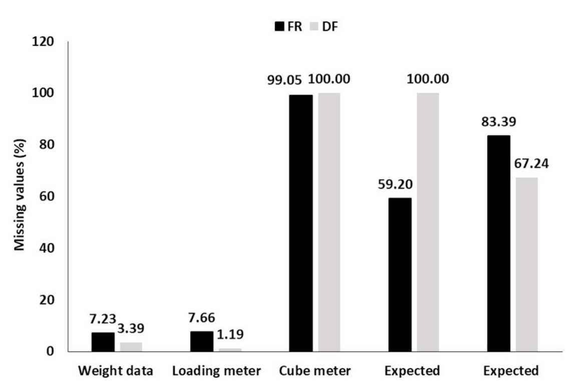


Fig. 4. Percentages of missing values in shared logistics data.

Fig. 5 shows the earliest and latest matching times on each day of the analysis period. The earliest and latest matching times are the times of first and last matching emails respectively. The results show that for all test days, the first matching email was sent around 6:00 AM while times of last matching emails differ among the test days. From a practical point of view, dispatchers might find matches at specific times more attractive than other times. For example, the early-morning matches (at 6 AM) might be unattractive since early-morning transport schedules are typically communicated to drivers a day before the execution. IS5 suggests that dispatchers can have an access to the CDSS to set their preferences regarding the earliest matching times (IS5) and latest matching times (IS6). IS5 and IS6 make it possible to filter matches according to the preferred times. This also leads to a fewer number of matching emails.

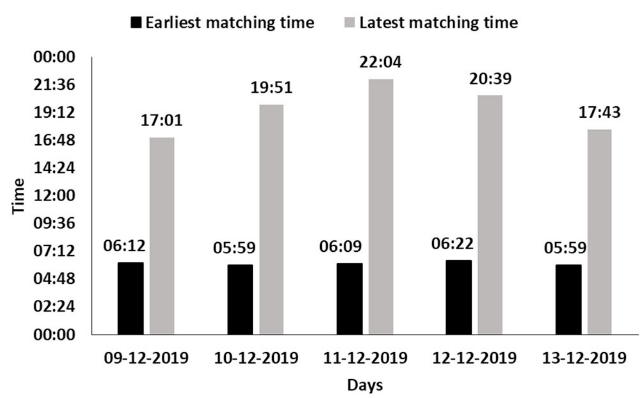
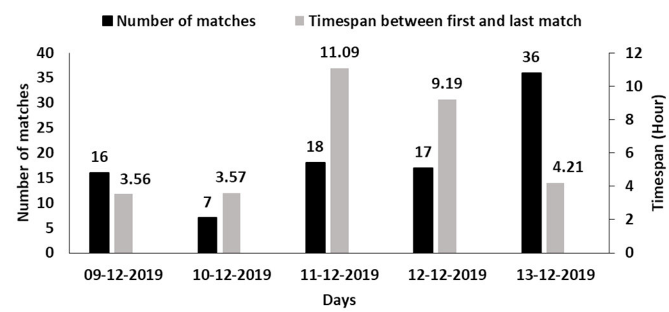


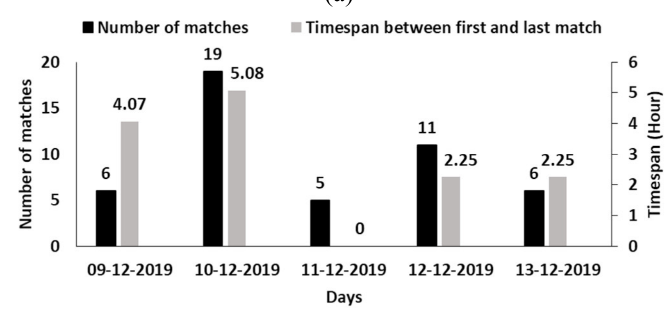
Fig. 5. Earliest and latest matching times at test days.

To identify the root causes behind increasing the number of matches, orders in each day were sorted ascendingly according to their numbers of matches. Then, the order with the maximum number of matches on each day was analyzed. Fig. 6 shows the numbers of matches and the timespan between the first and last match for the most matched order on each day. Two observations can be made from Fig. 6. The first observation is that an order had a relatively long time of 11 hours (fig. 6a). This occurs because carriers do not update their logistics data whenever an order is served and therefore, the CDSS continues sending matches for all orders as long as their statuses are not changed. This in turn not only rises the number of matches significantly but also, some matches may be invalid if the orders were served. Based on this observation, we suggest SI7: dispatchers set an automated matching time duration for their orders. The matching duration starts from the moment of uploading the order information into the CDSS. After this duration, the order is not matched. Dispatchers can set different matching durations for different load sizes. IS7 allows for reducing the number of matches and the probability of sending invalid matches. The second observation is from Fig. 6b which shows an order received five matches with a timespan of zero, meaning that this order was matched simultaneously to five different trailers. These five matches are sent as five order-matching emails to the order owner at the same time. Because the order-matching template does not display the matched trailer (see Fig. 2a), these five emails had the same email content. This made dispatchers think that the same email shows up multiple times simultaneously as indicated in Table 1. To overcome the issue, we suggest IS8*:* simultaneous matches of the same order are sent to the order owner as one email. By applying IS8, it is possible to reduce the number of matching emails.

The hourly distributions of the trailer matches were also conducted. Due to the page limit, the findings are only presented. It was found that the same trailer most often received more than one match, and some of them occurred at the same time. Similar to IS8, the number of trailer matching emails can be reduced by merging all simultaneous trailer matches into one email (IS9).



(a)



(b)

Fig. 6. The number of matches and timespan for the most matched order for DF (a) and FR (b).

To analyze the size distributions of matches, five categories of order size are created as shown in Fig. 7, which illustrates the relative frequency histogram of matches for both carriers. It can be noted from Fig. 7 that category#2 accounts for the highest proportion of total matches, followed by category#3, and category#5. To identify the categories being most attractive to dispatchers, a pairwise ranking survey was distributed to 11 dispatchers in both carriers. The results showed that the majority of dispatchers (when acting as trailer owners) prioritize matches of large sizes (the fourth and fifth categories) even if their trailers have excess capacity for small-sized orders. This might be because the service prices of large orders probably outweigh the cost of the additional traveling distances and handling costs, thus this always guarantees to make profits. This implies that if a dispatcher (when acting as the order owner) has a large order less than his truck capacity, he might prefer obtaining small orders over the one at his hand rather than sharing it. It is worth mentioning that our discussions with dispatchers indicated that some dispatchers misconceive the aims of the DiRECTLY-CDSS as an electronic platform for only getting full truckloads. Therefore, it is imperative to ensure that all dispatchers have better understandings of the developed CDSS and to increase their awareness about how the automated freight matching system can be used as a competitive advantage compared to their traditional ways of collaboration.

To improve the email readability, three ISs are also suggested as follows; SI10: Changing the title of order-matching email into 'Your order ID# has an exchange proposal', SI11:Changing the title of trailer-matching email into ' Loads are available near your trailer #ID', SI12:Visual display of orders' pickup locations on a geographical map in the trailer-matching emails.

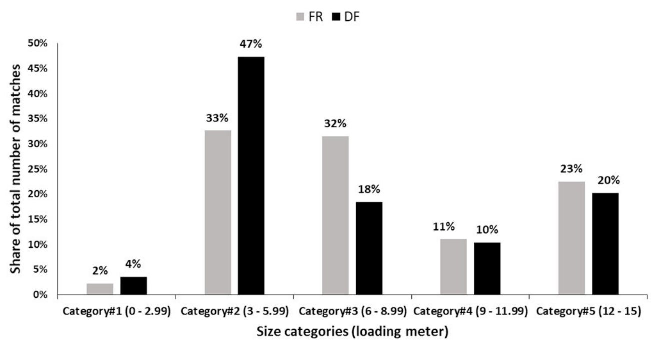


Fig. 7. The relative frequency histogram of size categories.

5.2 The impact of the improvement suggestions

Table 2 shows the impact of the proposed ISs on the CDSS performance. As can be seen from the table, some ISs, e.g., IS1 and SI0, can improve the email readability.

Table 2: The impact of the proposed ISs

ISs	Impact		
	Email readability	% reduction in the average number of matches	% reduction in the average number of matching emails
IS1	√	-	-
IS2	-	8%	Same as matches
IS3+IS4	-	17%	Same as matches
IS5	-	29%*	Same as matches
IS7	-	14%**	Same as matches
IS8	-	-	39%
IS9	-	-	36%
IS8+IS9	-	-	38%
IS10	√	-	-
SI11	√	-	-
SI12	√	-	-

* The preferred earliest matching time is set to 8 AM.

** The average matching duration is set to 5 hours, starting from releasing the orders into the CDSS.

6. CONCLUSIONS

This study discussed our experiences with testing an early version of a CDSS developed within the research project DiRECTLY. The developed CDSS is used to organize a collaborative transport network between two big carriers operating in Denmark with the intention of including other carriers at a later stage. Compared to existing studies on collaborative logistics, the current work shed the light on implementation issues rarely discussed in the literature. The test results showed that during the pilot test, dispatchers highlighted some issues, i.e. the high number of matches and matching emails, missing data values, low readability of Email templates. The analysis of the test results attracted our attention to twelve improvement suggestions which have been evaluated in a controlled environment. The results showed that the suggestions can improve the issues reported by the dispatchers. For implementing these suggestions, carriers have to get access to the CDSS so that they can set their matching preferences. At present, the main efforts are focused on implementing some of the proposed improvement suggestions into the CDSSs. Afterward, our attention will be paid to the next pilot test.

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